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FARMS: THE FLEXIBLE AGRICULTURAL ROBOTICS MANIPULATOR

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ABSTRACT

A technology utilization project was established with the Marshall Space Flight Center and the University of Georgia (UGA) to develop an earth based, robotic end effector to process live plant (geranium) material which will (A) improve productivity and efficiency in agricultural systems, such as, commercial nursery and green house systems; and (B) apply this technology to NASA's presence in space, including permanently manned space stations and, manned planetary communities requiring large scale food production needs (e.g. vegetable, fruits).

INTRODUCTION

A force-sensing robotic gripper system has been developed at the Productivity Enhancement Complex at the Marshall Space Flight Center. The reason for the robotic end effector development was to alleviate the labor intensive phases of plant production in commercial greenhouse operations.

Due to an increasing competitive world marketplace, automation is beginning to play a key role in the U.S. agriculture industry. The highly advanced growers of Western Europe and the low-cost growers of South and Central America have taken a large portion of the U.S. market in the last several years. For example, the number of cut flower growers in the U.S. has decreased approximately 75% since the mid-1970's in response to imports. In order for the U.S. greenhouse industry to maintain an economically sound industry, new production techniques must be adopted.

Robotics has great potential to meet the need for enhancing the productivity and quality of the U.S. greenhouse industry. Therefore, a robotic workcell has been developed at the University of Georgia Experiment Station, which is also where the MSFC gripper system is being tested and evaluated. The system is being evaluated on its ability to process geranium cuttings. The tedious labor required to process geranium cuttings and the high volume demand for the plant justified an attempt to automate this sector of the greenhouse industry.

The development of this robotic end effector technology was a joint effort between NASA/MSFC and the University of Georgia. The End effector was designed and developed at the MSFC/Productivity Enhancement Complex along with the microprocessor and software to perform the following functions:

1. Determine the cutting (geranium) orientation in perpendicular to the surface (Z-axis)
2. Picking up the cutting using a predetermined pressure
3. Measuring the diameter of the stem
4. Measuring the mass of the cutting
5. Trimming unwanted leaves from the plant
6. Trimming the plant to length
7. Pass cutting thru bend measurement sensor and orient the plant for potting
8. Inserting the plant in a potting trays

The system has been integrated with the UGA agricultural robotics research cell to process geranium cutting for transplanting. The UGA robotic workcell is composed of a 32 bit minicomputer with vision acquisition, an ASEA industrial robot, a parts conveyer and custom fabricated tools. The tasks of the robotic workcell are:

1. To detect cutting in robotic workspace and momentarily stop conveyer.
2. Perform automatic visual analysis.
3. Wait for robot to complete processing previous cutting.
4. Transmit data on cut and grasp locations, stripping requirements, and grade.
5. Automatically signal robot to begin processing, and restart conveyer.

OPERATION

The gripper system is composed of three subsystems: a closed loop force controlled DC servo actuated two fingered gripper, an industrial PC AT communications node and integral fiber optic analog output sensors used for part feature recognition.

During operation of the cell, geranium cuttings are placed on the conveyer manually. The conveyer indexes each cutting into the field of view of a CCD camera. The camera photographs the part and transmits the vision data to a 32 bit cell computer (Heurikon). The Heurikon calculates the position of the cutting in the XY plane defined by the surface of the conveyer belt. This data is formatted into ASEA robot commands and transmitted to the robot. The robot then moves to a location above the cutting. The arm searches along the negative Z-axis until the axial center line of the part is sensed using the fiber optic distance gauges. The analog output of the fiber optic sensors is sampled by the A/D card residing in the gripper node control. Upon recognition of the part, the gripper is closed using force feedback from a load cell internal to the gripper. Once the programmed force setpoint is obtained by the gripper, the resulting finger opening is stored by the gripper node control. This system caliper data is available to the Heurikon when needed.

The part is grasped by the gripper and carried by the arm to a trimming station. The trimming station removes the two petioles at the base of the stem and trims the base of the stem; the part is then placed in a fixture on an electronic balance. The balance is polled for the mass of the part by the gripper node control. This mass data is also available to the Heurikon when needed. The gripper is closed under force control a second time. The part is grasped by the gripper and carried by the robot arm to a stem alignment measurement station. Data from this station is used by Heurikon to command the robot to correctively place the stem into a potting tray. Upon completion of the cycle, the gripper is homed. The next cutting is positioned under the camera by the conveyer and the process is repeated.

GRIPPER/CONTROLLER DESIGN

HARDWARE

The force-sensing robotic gripper system contains four basic modules, namely the gripper, the Telerobotics controller enclosure, the Delta Tau SMCC-PC motion controller card, and two Banner photoelectric sensors (attached diagram).

The gripper consists of a precision servo motor driven, two finger, linkage parallel unit. The gripper uses an encoder for position indication and a miniature precision load cell for sensing the closure force between the two fingers. The gripper has a force range of 0 to 30 lbs with a force resolution of +/- 0.5 lb. The maximum closure rate is approximately 6 inches/second. The finger opening width is 4 inches. The gripper weighs approximately 6.5 lbs.

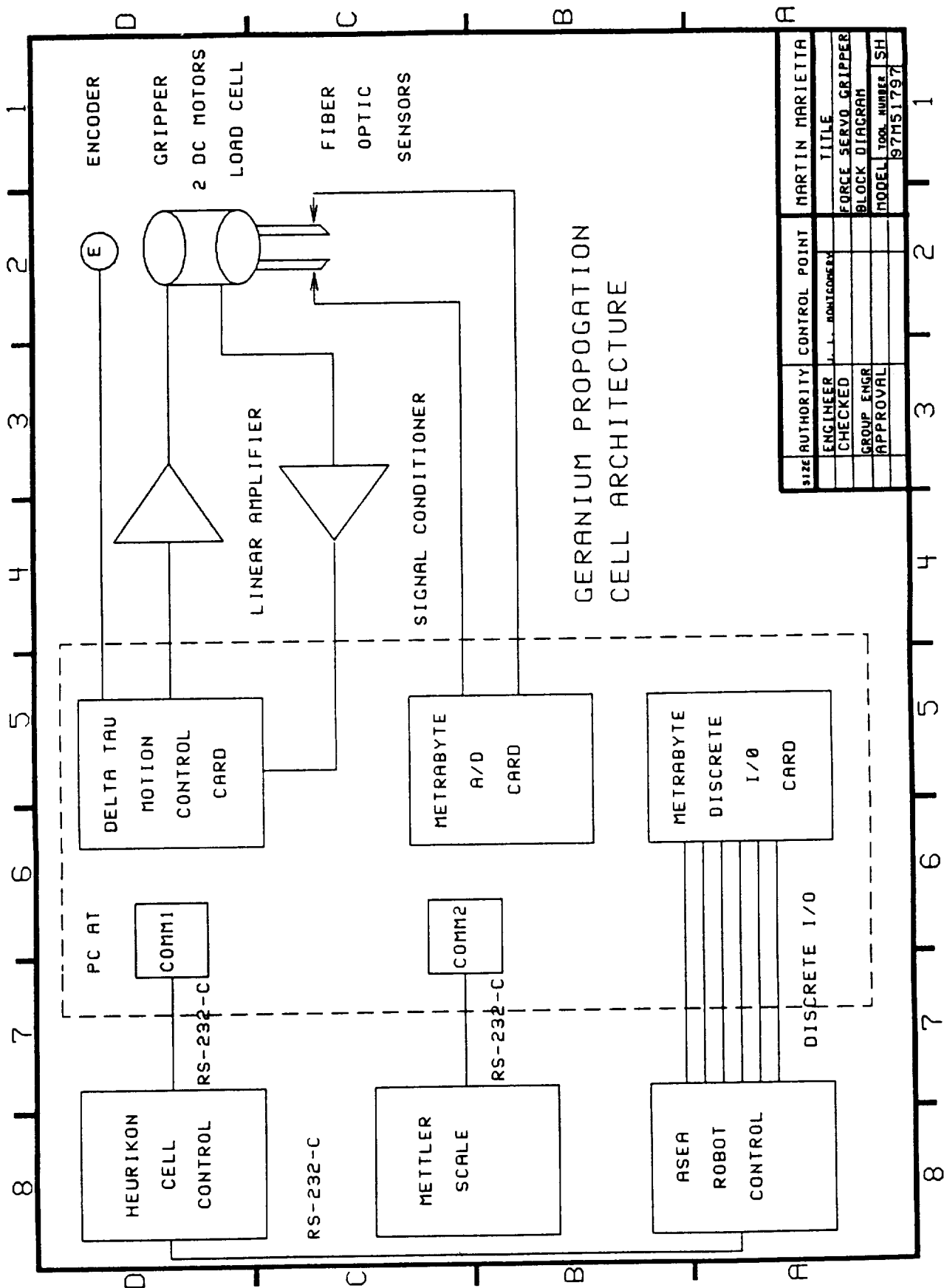
The gripper controller contains a driver-amplifier, a motor power supply, a low voltage power supply, and a signal conditioning board. The signal conditioning board prepares the load cell's signals for the motion control card contained in the PC. The motion control card is a full two axis digital PC card capable of receiving a variety of position, velocity, and analog signals. These signals are digitally processed by the system's software. The controller generates motor commands which in turn are executed and amplified by the driver-amplifier.

Due to the nature of the geranium cutting, the leaves of the plant forces the stem to be positioned slightly above the conveyor. Therefore, photoelectric sensors are used to assure that the robotic fingers will close directly onto the stem. The photoelectric sensors used are analog infrared scanners that provide a variable DC voltage output that is proportional to the strength of the received signal. The reason that the sensors are analog is that the gripper has to have the ability to distinguish between the stem and a branch of the geranium. If the sensor was digital and a branch interrupted the infrared beam, then the robot would stop prematurely. The sensors located on the finger tips of the gripper must be able to position themselves between the branches and stem of the plant. Therefore, the cables for these sensors have right angle deflectors.

SOFTWARE

The end effector controller system is a comprehensive group of IBM AT compatible based program modules developed and written in "C" language programming environment and a series of programs written in a language specific to the Delta Tau Motor Controller Card. The "C" program modules are combined in a task designed to initialize the hardware interfaces, provide a comprehensive variety of displays for operator interaction, and process a series of interactive commands received from a host processor or a robot controller to manipulate an end effector. The motor controller programs are kept in files on disk and are loaded into the motor controller card to perform the gripper functions.

Upon entry into the system, the interfaces, serial port (COM1) for communications with the host processor and serial port (COM2) for communications with the scale, are initialized, the optics interface, an A/D converter (DAS-16), the end effector interface, a motor controller (SMCC), and the robot interface, a parallel discrete I/O (PIO-24), are also initialized. The screen then displays the status window indicating the initial main menu node. From this point on, the system is very user friendly and in each of the selections provides the operator with a series of submenu menus to guide the operator through the process in an orderly fashion and with descriptive information and data displays for operator viewing. The remote operations selection from the main menu is the function that performs as an end effector controller and processes the commands received from the robot controller or the host processor. The commands to manipulate the end effector are performed by downloading a program into the motor controller card and running the program on the card. Command completion and information requests are returned to the initiator as required. The remaining selections from the main menu deal with test modes for the individual peripheral interfaces and the changing of parameters utilized by the end effector during remote operation.



SIZE	AUTHORITY	CONTROL POINT	MARTIN MARIETTA
ENGINEER	J. L. MONTGOMERY	TITLE	
CHECKED		FORCE SERVO GRIPPER	
GROUP ENGR		BLOCK DIAGRAM	
APPROVAL		MODEL	TOOL NUMBER SH
			97M51797

CONCLUSION

The design, fabrication, development, testing and evaluation of the force-sensing robotic gripper system was performed by NASA and Martin Marietta personnel at the Marshall Space Flight Center. The implementation of the gripper system into the University of Georgia's robotic workcell was successful. Test results indicate that the force-sensing gripper does not crush or bruise the plant. The results also show that the percent of successful robot cycles is approximately 90 percent. However, the photoelectric sensors slow the robot's cycle time by 1 to 2 seconds which gives the workcell a cycle time of 6 to 7 seconds.

The development of the robotic workcell is still in process at the University of Georgia. The MSFC is supporting any enhancements or modifications to the gripper system and the robotic workcell. Modifications to the workcell's vision system and feeder system is currently in process. As soon as the workcell has been optimized in the laboratory, it will then be installed in the greenhouse for further testing. If the results from these tests are successful, then this technology may be applied to greenhouses across the U.S. or even in a greenhouse in a prolonged space habitat.

ACKNOWLEDGEMENTS

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